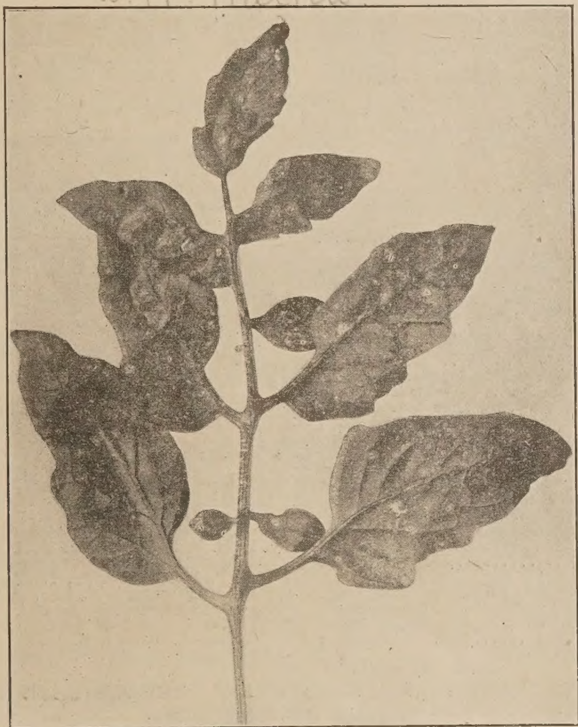
1920

BULLETIN 345

Studies on Tomato Leaf-Spot Control

W. H. Martin



Tomato Leaf-Spot

NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS

NEW BRUNSWICK, N. J.
November, 1920

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NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS
BULLETIN 345
OCTOBER 1, 1919

STUDIES ON TOMATO LEAF-SPOT CONTROL

WILLIAM H. MARTIN, PH. D., *Associate Plant Pathologist*

Introduction

Leaf Spot, caused by *Septoria Lycopersici* Speg., is one of the most common and destructive diseases of the tomato in New Jersey. No accurate statement of losses resulting from attacks of this fungus can be made, but numerous instances have been noted where the yield was seriously reduced, while in some cases the crop has been a complete loss.

Where tomatoes are grown principally for home consumption, the losses resulting from an outbreak of this disease are of little consequence. However, where tomatoes are grown extensively for both the market and the cannery, as in many sections of New Jersey, the losses assume considerable economic importance. Whereas ten years ago, a 12 or even 15-ton yield was by no means uncommon, it is doubtful if the average for the past five years will exceed 5 tons. While other causes may have been factors in bringing about this decrease in yield, we are led to believe that leaf spot has been the most important agency.

Because of the serious losses experienced by the tomato growers of the state, the department of plant pathology of the New Jersey Agricultural Experiment Station conducted experiments to determine whether or not this disease could be controlled by spraying. At the same time, studies were made to determine the means by which the causal organism was disseminated. These experiments were conducted over a period of three years and the more important results are presented in this bulletin.

Preliminary experiments were conducted at Riverton in 1915. In 1916, the experiments were at Salem, the Truck Crop Laboratory of the U. S. Bureau of Plant Industry and the H. J. Heinz Company cooperating. This work was designed to determine (a) to what extent leaf spot could be controlled by spraying with Bordeaux mixture, (b) the best strength of Bordeaux mixture to be used, and (c) the relation of time of application to control. In 1917 the

work was done at Riverton in cooperation with the U. S. Truck Crop Laboratory and the Campbell Soup Company, the scope of the work being broadened to include tests of certain spray mixtures developed by F. J. Pritchard and W. B. Clark of the Bureau of Plant Industry.

General Historical Account of the Disease

The first description of leaf-spot of tomatoes was given by Spegazzini (1882) who discovered the fungus in Argentina. Following this first record the disease was reported as occurring in Argentina, Italy, Australia, France, Germany, Austria, Hungary, Transvaal and England.

In the Unted States the leaf spot was first reported in 1895 by Halsted (8) of New Jersey. At that time he noted it as being one of the most serious diseases of the tomato. Halsted was probably the first to attempt the control of leaf spot by spraying. Selby (18) writes of finding the disease in Ohio, and in a later paper (19) he discussed its distribution in the state as well as the probable time of its appearance. Powell (16) reported it as being prevalent in Delaware and gives the results of two years' spraying experiments for its control. Rodgers (17) notes its occurrence in California but states that while plants in the seed-bed are affected climatic conditions prevent serious loss in the field.

Symptoms

The disease first appears on the older leaves of a plant. The first indication of its presence is the formation of small, almost indistinguishable water-soaked areas on the under leaf surface. As the disease progresses, these areas become more definite in outline and the tissue becomes dry. The spots measure from several millimeters to several centimeters in diameter. Many spots frequently coalesce. When this condition is reached the intervening green tissue soon dies, the leaf remaining on the plant in this condition until removed by wind or other agents. In cases of heavy infection, it is not uncommon to find plants bare of all living leaves except a few newly formed leaves at the apex.

The disease is to be found also on the stem where it forms elongated spots. Here the damage is by no means as severe as on the leaf. Indirectly, however, stem infection is important since the spots serve as infection centers for further distribution.

Floyd (6) states that in Missouri, leaves, stems and green fruit are affected, small black spots being formed on the latter. In New Jersey the disease has not been reported on the fruit. The writer has examined large numbers of green and ripe fruit with negative results.

Dissemination of the Causal Organism

Various explanations have been offered to account for the dissemination of the organism causing leaf spot. Cook (5) and

Stuckey (22) state that it lives from year to year in the old vines and is carried to the field on the young plants. Levin (11) found that an increase in the fungous thallus had occurred on over-wintered stems and leaves and that spores from pycnidia from old vines germinated to the extent of 10 per cent. This writer expresses the belief that this is the main source of infection. Instances have been noted where the disease made its first appearance in restricted areas from which centers of infection the fungus soon spread to all parts of the field. Since it is evident that distribution through the soil is necessarily a rather slow process some other factor or factors must be considered in connection with this rapid spread of the disease.

In the work here reported four agents were considered as possible carriers of the organism: (a) insects, (b) water, (c) wind and (d) pickers.

Dissemination By Insects

A review of the literature on the question of dissemination of the causal organisms of plant diseases will reveal the importance attached to insects as carriers. Only a few references can be cited here.

Grossenbacher and Duggar (7) have demonstrated that *Botryosphaeria ribis* causing late blight of currants may be carried by insects. They state that the currant borer feeds only on the sclerotia and stromata of the fungus, the insect never being observed in plantations free from the disease.

Another well known example of the distribution of fungous spores by insects is found in a study of the life history of *Glomerella rufomaculans* (Berk., Spaulding and Van Schrenk) which causes bitter rot of apples. Clinton (4) demonstrated by inoculation experiments that flies of the genus *Drosophila* carried the spores of the fungus. Burrill (3) conducted successful inoculation experiments with crushed flies indicating that spores in the alimentary tract were viable.

Insects have been shown by Jones, Giddings and Lutman (10) to be carriers of *Phytophthora infestans* (Mont.) De Barry the cause of late blight of potatoes. When larvæ of the Colorado beetle were transferred from diseased to healthy plants, signs of the disease appeared after 6 days. These writers express the belief that the mature beetles are important agents in the distribution of the fungus in the early stages of the development of the disease.

In an extensive paper having an important bearing on the question of dissemination of fungous spores by insects, Studhalter and Ruggles (23) found that spores of *Diaporthe parasitica* Murrill are carried by insects of the following orders, *Hemiptera*, *Coleoptera*, *Diptera* and *Hymenoptera*. The majority of insects examined were found to carry the spores in large numbers. Wolf (25) found that insects function in the distribution of the fungus

causing peanut leaf spot. He found that alimentation did not destroy the power of germination, instances being noted where some spores were germinating at the time of discharge. Among other spore forms found in addition to *Cercospora personata* were *Puccinia Cassipes*, *Alternara* sp. *Fusarium* sp., *Helminthosporum* sp., and *Ravenelia* sp.

In New Jersey the tomato is attacked by the Colorado potato beetle *(Leptinotarsa decemtiveata* Say.), with their larvæ, flea beetles and hornworms *(Phlegethontius quin-quemaculata* Haworth) in large numbers, the first two frequently becoming so abundant as to necessitate spraying for their control. Since these insects are present until late in the season it would appear that a large majority of the plants in a field are visited at some time during the growing period.

Observations made by the writer during the summer of 1917 would indicate that spores of the early blight fungus *(Alternaria solani* E. and M.) are carried by flea beetles, punctures frequently being the center of an early blight infection. It cannot be concluded from this that the spores were deposited on the leaf by the flea beetles since the puncture alone may have presented a condition favorable for infection which was later brought about by wind-carried spores. From the large number of observations, however, the evidence would point to direct infection by spores carried by the beetles. In this work, insects and fecal deposits were collected directly from plants in the field and examined for the presence of spores. In other cases, insects were allowed to feed on the diseased leaves when a similar examination was made.

Insects Collected in the Field

The insects used in these tests were collected from diseased and healthy plants. They were removed from the plant by means of a pair of forceps and transferred to small glass vials in which they were taken to the laboratory and examined for the presence of spores.

The method employed in removing the adhering spores was as follows. A drop of sterile water was placed on a glass slide and the insect to be examined was held in the water by means of a pair of sterile forceps. The movement was sufficient to remove the adhering spores.

The results of these examinations are given in table 1.

Cases were noted where the insect examined was found to carry no spores. This was to be expected, however, since they were collected early in the season when there was little of the disease present in the field. As the season advanced and the disease became more prevalent all the insects examined were found to carry large numbers of spores, as many as 225 being found on one individual.

After August 7, many of the insects examined were found to carry spores whether taken from a diseased or a healthy leaf. This would indicate that those taken from a leaf free from the disease had previously visited a diseased leaf. In this connection the question arises as to whether the spores would be deposited on a leaf as a result of the normal activities of the insect. In a recent paper Studhalter and Ruggles (23) demonstrated that spores of the chestnut blight fungus were easily shaken from the body of the beetle *(Leptostylus macula)* by its own movements. Since this is true, it is reasonable to believe that insects would deposit some of the spores carried as they passed from leaf to leaf, and this would appear to be especially true were there any moisture present on the visited leaf.

TABLE 1

Number of spores found on insects collected in the field

Insect	Date collected	Number of Spores: *S. lycopersici*	Number of Spores: *A. solani*
Larva of Colorado potato beetle *L. decemlineata* Say	July 23	25	10
	July 23	24	4
	July 23	36	0
	August 7	10	0
	August 7	60	90
Tomato worm, *P. Carolina*, Linn.	August 7	90	7
	August 7	106	6
	August 7	36	13
	August 7	80	16
Colorado potato beetle (adult)	August 17	160	11
	August 17	27	0
	August 17	225	2
	August 17	200	2
	August 17	100	5
	August 17	190	4

Spores of both the early blight and leaf spot fungi were observed to be germinating when removed from the insect. The insects from which these spores were taken were collected early in the morning when dew was still present on the leaf, thus affording an ideal condition for germination of spores.

Insect Excreta From Plants in the Field

Insect excreta were collected from leaves and stems free from disease in order to avoid removing spores from the diseased areas and thus greatly increasing the count. The deposits were removed by means of a sterile scalpel and placed in a glass vial. An examination of this material was made difficult because of the presence of undigested plant tissue; consequently it is possible that some spores were counted twice while others may have been missed.

Table 2 gives the number of spores observed in the fecal deposits examined. While the number noted is in no case large, still the results show that spores are carried in the excreta. Instances were observed where *S. lycopersici* and *A. solani* spores were germinating, indicating that alimentation does not destroy their viability. This is of considerable importance, since, if the spores are viable when excreted, these deposits make an ideal medium for germination and subsequent infection of the underlying plant tissue.

TABLE 2

Number of spores observed in insect excreta collected from healthy leaves in the field

Date of collection	Number of Spores	
	S. lycopersici	*A. solani*
July 23	24	0
July 23	7	0
July 23	34	0
August 6	7	4
August 6	10	3
August 16	40	0
August 16	30	1
August 16	25	0

Insects Allowed to Feed on Diseased Leaves

Tomato leaves affected with leaf spot and early blight were placed in moist chambers together with insects. The insects were allowed to feed over night when they were removed and examined for spores. The method employed in making this examination was the same as that described above for insects collected in the field.

The results of these examinations are given in table 3. All the insects examined were found to carry spores, as many as 250 being obtained from one individual.

Hornworms were found to carry large numbers of spores. It was found that on applying pressure to these insects they threw out a fluid which on examination was found to contain large numbers of spores of both the early blight and the leaf spot fungi. Tests conducted with this material showed that all of the *Altenaria* and a large per cent of the *Septoria* spores were viable. It is extremely doubtful if the hornworm plays an important role in dissemination, however, since it is usually not present in large numbers and the individual does not travel far.

Excreta from Insects Feeding on Diseased Leaves in Moist Chambers

Excreta taken from the moist chambers were found to contain large numbers of the spores. To avoid the error which would arise from removing some of the spore mass from the diseased leaves

along with the fecal deposits the following method was employed. An insect was removed from the diseased material and after being carefully washed was placed on a glass slide where the fecal material was caused to be deposited by applying pressure on the abdomen with forceps. In this way no spores other than those in the deposits were taken.

TABLE 3

Number of spores from insects kept in moist chambers with diseased plants

Insect	Number of Spores	
	S. lycopersici	*A. solani*
Larva of Colorado potato beetle *L. decemlineata*, Say	10	0
	100	0
	150	0
	100	4
	70	3
	21	0
	65	7
	100	5
	200	0
	250	3
	150	0
Tomato worm *P. Carolina* Linn	75	10
	100	10
	75	0
	50	5
Lady-bird beetle *C. novemnotata* Host	250	0
	70	0
	50	5
Colorado potato beetle (adult)	75	0
	30	0
	60	4
	40	1
	39	4
	42	10
	29	0
	21	0
	75	0
	22	4
	19	6

The results of these examinations and of those made of the fecal deposits collected from plants in the field indicate, beyond doubt, that insects feed on the diseased material and probably on the spores themselves. To determine whether or not the spores were viable after passing through the digestive tract, slides with the macerated excreta were placed in moist chambers and examined from time to time. In most cases, germination of the *Alternaria* spores appeared to be affected very little. The per cent of germina-

tion of these *Septoria* spores was lower than the germination of spores taken directly from pycnidia.

These results demonstrate that the spores of *Septoria lycopersici* are carried not only on the bodies of insects but in the digestive tract as well, and that the excreted spores are viable. It is believed, however, that too much importance should not be attached to insects as factors in the dissemination of the leaf spot fungus. While the larvæ of the Colorado potato beetle were shown to carry large numbers of spores it is doubtful if they are of importance except in carrying the disease to different parts of the individual plant. The mature beetle, however, visits a large number of plants so that

TABLE 4

Number of spores observed in excreta from insects taken from diseased leaves in moist chambers

Date of Observation	Number of Spores	
	S. lycopersici	*A. solani*
July 19	45	0
July 19	40	0
July 19	16	0
August 7	28	2
August 7	39	1
August 7	12	4
August 7	19	0
August 7	150	0
August 7	40	0
August 7	30	1
August 7	19	0
August 7	10	0

more importance may be attached to them as carriers. The fact that very often the majority of these insects disappear from a field before the disease becomes severe, would tend to eliminate them as important factors in the dissemination of the fungus. It is believed however, that they function in the early distribution of the disease and this is of extreme importance, since serious difficulty is experienced in controlling this disease after it has once become established in a field.

Wind as a Factor in Dissemination

It has long been recognized that wind plays an important role in the dissemination of the causal organisms of some of our common plant diseases. McCarty (13) states that mature spores of the apple rust fungus *(Gymnosporangium macropus* Lk.) may be carried 4 miles in an unusually high wind.

Wolf (25) demonstrated that the spores of *Cercospora personata*, the cause of peanut leaf spot, are carried by the wind. No tests were made to determine how far the spores were carried, but exposures made 8 feet from infected plants showed their presence.

In a series of experiments Burrill (3) showed that the fungus causing bitter rot of apples may be carried by wind. Tests were made by exposing funnels in the vicinity of diseased trees. At the outlet of the funnel, cups containing glass wool moistened with a mixture of glycerin and alcohol were attached. An examination showed that a number of spores were caught in these funnels. He attaches considerable importance to the results of these experiments and expresses the belief that they would help explain some very troublesome questions that have arisen as to the possible mode of distribution of this organism.

Burrill (3) and Barrett and Burrill (2) in their investigations of the ear rots of corn found that *Diplodia sp.* spores are carried as far as 350 yards by the wind. In one instance, where the test was performed within a few feet of a diseased plant, there was a tendril present indicating that more than a single spore may be carried.

Levin (11) advances the opinion that spores of *Septoria lycopersici* may be washed from the plant to the soil, from whence they are carried by the wind in dust particles to other plants.

As in the case of the fungus causing bitter rot of apples and the one causing the blight of chestnut trees, the spores of *S. lycopersici,* as they issue from the pycnidia are imbedded in a mucilaginous substance which hinders free dissemination by wind. The fact that it has been demonstrated that the spores of the first two mentioned forms are carried by wind led to experiments to determine whether or not spores of the leaf-spot fungus are disseminated in the same way. There is reason to believe that there is little wind dissemination of this type of spore during hot, dry weather. The substance in which the spores are borne becomes hardened during dry weather so that they would be removed with difficulty by air currents. After a rain or heavy fall of dew, this sticky substance is dissolved and the spores lose their cohesive character. In this condition their minute size renders wind dissemination possible.

Funnels similar to those employed by Burrill (3) were constructed to determine if spores of the leaf spot fungus were wind-carried. They were made 18 inches across at the wide end and 1 inch at the exit. Over a collar soldered to the exit was fitted a cup made of fine-mesh brass wire. A layer of glass wool saturated with glycerin and alcohol was placed in the cup to catch the spores. Each funnel was attached to a 3-foot pole and adjusted in the field with the open end to the wind. After being exposed for a definite time period the cups were taken to the laboratory where the glass wool was removed and washed in a small quantity of distilled water. An examination was then made of a uniform amount of wash water from each exposure for the presence of spores.

Table 5 gives the number of spores observed at different times during the summer. The first column of the table gives the place and date of exposure; the second column the duration of the exposure. In the last three columns are recorded the number and kind of spores observed.

TABLE 5

Number of Spores Observed in Spore Traps

Place and Date of Exposure	Time of Exposure	Number of Spores Observed		
		Septoria	*Alternaria*	
Potato field				
August 10	1 hour	..	18	..
August 10	4 hours	..	29	..
Tomato field	2 p. m. to 4 p. m.			
August 14	2 p. m. to 4 p. m.	4	1	0
August 14	2 p. m. to 4 p. m.	6	1	0
August 14	2 p. m. to 4 p. m.	2	3	0
August 14	2 p. m. to 4 p. m.	0	4	0
August 14	2 p. m. to 4 p. m.	1	1	0
Tomato field	12 p. m. to 6 p. m.			
August 27	12 p. m. to 6 p. m.	5	3	0
August 27	12 p. m. to 6 p. m.	4	3	0
August 27	12 p. m. to 6 p. m.	4	6	0
August 27	12 p. m. to 6 p. m.	6	17	1
Tomato field	Overnight			
September 3	Overnight	21	29	0
September 3	Overnight	35	8	0
September 3	Overnight	20	39	2
Tomato field	8 a. m. to 6 p. m.			
September 8	8 a. m. to 6 p. m.	3	20	4
September 8	8 a. m. to 6 p. m.	11	16	3
September 8	8 a. m. to 6 p. m.	10	15	1
September 8	8 a. m. to 6 p. m.	8	9	10

Preliminary tests were conducted by exposing two of the funnels in a potato field in which the majority of plants were affected with early blight (*Alternaria solani* E. & M.). In the first funnel, exposed for 2 hours, 18 *Alternaria* spores were counted, while in the second, exposed 4 hours, 29 spores were observed.

The remaining tests were conducted in a tomato field. While leaf spot was very severe in this field very few of the diseased areas on the leaves were fruiting. This may account for the fact that a larger number of spores were not caught during the time through which the exposures were made. While the number of spores caught was not large, the results would indicate that some importance may be attached to wind as a factor in their dissemination.

The results likewise demonstrated the action of water as an aid to wind dissemination. The funnels exposed September 3 were set up at 7 p. m. and allowed to remain until 10 o'clock the following morning, when the cups were removed. During the night there was a heavy dew that could be expected to dissolve the sub-

stance in which the spores are embedded. As a result of this, they were in a condition favorable for wind dissemination. On the other hand, in the tests conducted September 8 the funnels were exposed on a day of no moisture and the number of spores carried was considerably less.

It will be noticed that the number of *Alternaria* spores is greatly increased and that some *Fusarium* spores were caught on the last days on which tests were conducted. This is believed to be due to the fact that these spores were blown from decaying fruit on which both of these fungi were present in abundance.

Considerable importance is attached to the results of these experiments. In the past, the question of dissemination of this organism from infection centers has largely been a matter of conjecture. From the light of the present evidence, it would appear that wind plays an important role in its distribution. This fact has an important bearing on control measures, making it imperative that spraying operations be undertaken when the disease is observed in any part of the field in order to prevent general distribution of the fungus. Barker and Cunningham (1) have shown that germ tubes of fungous spores exert considerable solvent action on copper compounds with which they come in contact, and that a rapid absorption of the copper followed by death of the cells takes place. If this is true, an application of Bordeaux mixture or similar spray applied when the disease is first observed may be expected to cover the susceptible plant parts with a protective film that will prevent germination and subsequent infection by the wind-blown spores.

Water as a Factor in Dissemination

Warm, sultry weather accompanied by rains furnishes conditions favorable for the development of many fungi of economic importance. It is apparent that this is due to the favorable conditions afforded for development, but it is believed also that during a period of this kind abundant dissemination takes place by the mechanical action of rain. Levin (11) demonstrated this to be true under greenhouse conditions. Healthy tomato plants were distributed among diseased plants and all were irrigated from below. After 25 days, the healthy plants showed no indication of the disease. The plants were then watered from above so that the water splashed from one leaf to another; in 6 days all the plants were covered with typical leaf-spot infections. Whetzel (24) notes that bean anthracnose [*Colletotrichum lindemuthianum* Sacc. and Magn. (Bri. and Cav.)] may be carried by wind during seasons of wet weather.

The presence of dew also may be expected to be a factor of considerable importance in local dissemination and consequent infection. It is extremely doubtful if this would be a factor in the general dissemination of the organism, but it would explain the distribution of the spores from one part of a leaf to another or to other leaves on the same plant.

Table 6 gives the results of examinations made of water collected from various parts of tomato plants after a rain or heavy dew. This water was collected from the different leaves by means of a sterile pipette and transferred to a glass vial. The first examination was made of water taken from a diseased leaf that bore pycnidia; each drop was found to contain an average of 65 spores. This would serve to explain the secondary infection so frequently observed on a leaf which appears as a number of smaller spots surrounding the mature ones. No doubt these immature lesions are produced by spores which floated out from the pycnidia formed in the older spots.

TABLE 6

Number of spores observed in water from plants in the field

Source of Material	Number of drops examined	Number of Spores Observed		
		Septoria	*Altenaria*	*Fusarium*
Leaf infected with *Septoria*.	6	391	0	0
Upper surface of clean leaves, top of plant......	30	8	0	2
Upper surface of clean leaves, top of plant......	5	6	8	0
Upper surface of clean leaves, top of plant......	30	3	3	1
Lower surface of clean leaves, top of plant......	30	17	5	7
Upper surface of clean leaves, base of plant......	30	50	0	3
Upper surface of mud-splashed leaves, base of plant	30	88	3	3
Lower surface of clean leaves, base of plant......	30	31	1	1
Lower surface of clean leaves, base of plant......	30	24	3	6
Lower surface of mud-splashed leaves, base of plant	30	19	1	1

Very few spores were found in the water collected from the upper surface of healthy leaves at the apex of the plant. It is doubtful if the spores observed were carried there by water, the plausible explanation being that they were carried by wind or possibly the combined action of wind and water. The lower surface of these leaves showed a larger number of spores, but even here the number was by no means great; it would appear that these spores, for the most part, were carried here by the splashing of falling rain.

An examination of the water taken from the upper and lower surfaces of leaves at the base of the plant revealed the presence of large numbers of *Septoria* spores. In one instance, where water was taken from a mud-splashed leaf, as many as 88 spores were found. This would tend to substantiate the claims of previous in-

vestigators who stated that spores may be washed to the ground and deposited on the plant by the splashing of rain. On the other leaves also, free from deposits of soil, numerous spores were observed. Their presence on the leaf may be accounted for in the same manner. In many of the samples examined instances were noted where both *Septoria* and *Altenaria* spores had already sent out germ tubes preparatory to entering the leaf.

The results of these observations emphasize the importance ot water as a factor in the dissemination of the spores of *Septoria lycopersici.* It would appear that it plays an important role in the spread of this organism over different parts of the same plant. It is also believed that water is of considerable importance in the dissemination of these spores by wind, since the results of these studies and those of other investigators would indicate that little wind dissemination takes place during dry weather.

Pickers as Agents in Dissemination

It is frequently stated, but usually without experimental evidence, that man is a factor in the distribution of the organisms causing some of the common diseases of plants. A review of the literature revealed little evidence of a direct nature on the question of the dissemination of fungi by workmen. The following tests were made to determine to what extent leaf-spot is disseminated by human agents. The method employed was to scrape the hands and garments of pickers by means of a scalpel. A small quantity of distilled water was added to the material collected in this manner and it was examined for the presence of spores.

TABLE 7

Number of spores observed in material scraped from pickers' hands and garments

Source of Material	Number of drops examined	Total number of spores	
		S. lycopersici	*A. solani*
Hands (plants slightly infected)	6	17	43
Garments (plants slightly infected)..	7	3	12
Hands (plants severely diseased)....	10	692	17
Hands (plants severely diseased)....	10	480	50
Garments (plants severely diseased)	10	50	3

The results of the examinations are given in table 7. This material was collected from two different sources. In one case the pickers had just finished picking a field in which little leaf-spot was present. The other material was taken from pickers at work in a field in which the disease was very severe. In every case the material to be examined was collected at a time when there was little moisture on the plants, so that it is to be expected that, had the

plants been wet, the spore count would have been considerably larger.

It will be seen from the table that comparatively few spores were observed in the material from the field in which there was little infection, while large numbers were obtained from the heavily infected field. It will be noticed also that the number of spores removed from the hands is considerably greater than the number removed from the garments.

This may be explained by the fact that in picking tomatoes, it is necessary to turn over many of the vines in order to reach the fruit and also by the fact that leaf-spot infection is usually more severe on the lower leaves.

It very frequently happens that leaf-spot becomes especially severe after the second picking. In view of the fact that the picking dates are usually a week apart, and that it takes about 10 days for the disease to become apparent, it would appear that this may be traced to the first picking. As has been indicated, the pickers find it necessary to move many of the vines. In doing this, they necessarily come in contact with diseased leaves, the sticky spores adhere to their hands and are carried to the next plant. In this manner their activities would be of more or less importance in the dissemination of the fungus.

From these results it seems advisable that pickers be kept out of a field after a heavy rain, or a heavy dew, until the plants are dry. When the plants are wet the spores are readily carried and are deposited on other leaves where the moisture presents conditions highly favorable for germination. Near the end of the season delaying picking would hardly be necessary, but in the early season when the plants have yet to set a large part of their fruit, it would be well to delay picking until the plants are dry.

Control Measures

The only measures which might be expected to control leaf-spot are spraying, or the development of disease-resistant varieties. While some work has been done to develop a strain of tomatoes resistant to leaf-spot, the results to date offer little encouragement, so control measures must be based on protection by spraying.

The first record of tomato-spraying experiments for the control of leaf-spot is that made by Halsted (8), whose investigations continued over a period of 5 years. The results of these experiments are summarized in table 8.

It will be noted that several spray mixtures were used, the plots sprayed with Bordeaux mixture giving the greatest return in most cases. The average increase of the plots sprayed with Bordeaux was 23 per cent while the remaining sprayed plots showed an increase of 12 per cent. The fact, however, that none of the plot

treatments were repeated and that very few check plots were employed would render it doubtful whether or not the increase noted can be attributed entirely to disease control, since considerable differences may result from soil variation.

TABLE 8

Summary of Tomato-Spraying Experiments Conducted in New Jersey 1895 to 1900

Year	Spray Material	Number of applications	Date of applications	Increase in Yield
				per cent
1895	Copper-sulfate plus soap......	?	?	0
1895	Copper-sulfate without soap..	?	?	0
1895	Eau Celeste..................	?	?	0
1896	Soda-Bordeaux	14	10-day intervals May 25-Oct.	30
1896	Bordeaux, 4-4-50.............	14	May 25-Oct.	39
1896	Potash-Bordeaux	14	May 25-Oct.	1
1897	Soda-Bordeaux	12	10-day intervals May 22-Oct. 4	39
1897	Hydrate	12	May 22-Oct. 4	1
1897	Bordeaux	12	May 22-Oct. 4	30
1897	Potash-Bordeaux	12	May 22-Oct. 4	27
1898	Creolin	10	10-day intervals June 1-Sept. 23	13
1898	Creolin	10	June 1-Sept. 23	9
1898	Soda-Bordeaux	10	June 1-Sept. 23	13
1898	Bordeaux	10	June 1-Sept. 23	32
1899	Bordeaux	11	10-day intervals June 2-Sept. 13	10
1899	Soda Bordeaux	11	June 2-Sept. 13	10
1900	Bordeaux	9	10-day intervals June 11-Sept. 24	23
1900	Bordeaux	9	June 11-Sept. 24	7

TABLE 9

Summary of Tomato-Spraying Experiments Conducted in Maryland

Year	Spray Material	Number of Applications	Time of Application	Increase in Yield
				per cent
1896	Bordeaux	4	June 6-July 28	36
1897	Bordeaux	3	July 14-August 6	27
1896-97	Bordeaux	3-4	July 14-August 6	..
1896-97	Bordeaux	3-4	July 14-August 6	52
1898	Bordeaux	3	Seed-bed and 2 times later	90
1899	Bordeaux	?	?	35
1913	Bordeaux	5	Throughout season	12

Norton (14) reports tomato-spraying experiments conducted over a period of 7 years. His results are summarized in table 9.

It will be seen from the table that results of a positive nature followed the spray-applications. Norton states that more than a

10 to 20 per cent increase may be expected where spraying is begun early and continued throughout the season, at least 5 to 7 applications in all being made.

Powell (16) also secured an increased yield as a result of spraying, in one experiment amounting to 37 per cent. This increased return can hardly be attributed to disease control alone, however, since he states that both sprayed and unsprayed plants lost their leaves.

Spraying Experiments at Salem

In 1916 the writer conducted experiments for the control of leaf-spot at Salem. The plots in this work were made ¼-acre in size and, to eliminate possible differences resulting from soil variations, each treatment with its check was repeated three times.

Three strengths of Bordeaux mixture were used, as follows:

(a) 4 pounds of copper sulfate and 4 pounds of lime to 50 gallons of water (4-4-50); (b) 2 pounds of copper sulfate and 3 pounds of lime in 50 gallons of water (2-3-50); (c) 6 pounds of copper sulfate and 4 pounds of lime to 50 gallons of water (6-4-50). The experiment was designed also to determine the best time of making the spray applications as well as the number of applications giving best results. On some plots the first application was made in the seed-bed and continued throughout the season, on others the early applications were omitted, while in others the late applications were omitted. In all there were 7 different treatments as follows:

Plot 1. 4-4-50 mixture, one application in the seed-bed and five in the field on the following dates: June 23, July 6, July 18, August 7 and August 21.

Plot 2. 4-4-50 mixture, June 23, July 6, July 18, August 7, and August 21.

Plot 3. 4-4-50 mixture, July 18, August 7, and August 21.

Plot 4. 4-4-50 mixture, July 6, July 18, August 7, and August 21.

Plot 5. 2-3-50 mixture, June 23, July 6, August 7, and August 21.

Plot 6. 6-4-50 mixture, June 23, July 6, August 7, and August 21.

Plot 7. 4-4-50 mixture. June 23, July 6, July 18, and August 7.

The plots were arranged in the following order: check, two treated plots and a check. This was continued throughout the series and the series was repeated three times. This gave 12 check plots and 21 sprayed plots.

The arrangement of the plots with the yield per acre for each plot is given in table 10.

In the work at Salem, the treated plots in every case gave an increase over the adjoining check plots, regardless of the strength of the mixture, the time of application or the number of applications. It must be stated, however, that very little control of leaf-spot resulted from the treatments, the sprayed plots looking little better than those not sprayed. The increased returns from the sprayed plots may be attributed to several causes. The presence of Bordeaux mixture, acting as a repellant, protected the young

plants from insect attacks while the unsprayed plants were severely injured. The stimulative action of the copper in the spray also may be partly responsible for the increase, although no positive statement to this effect can be made. Of the sprays used the 4-4-50

TABLE 10

Results of Tomato-Spraying Experiment Conducted at Salem

Plot	Treatment	Yield per Acre	Plot	Treatment	Yield per Acre	Plot	Treatment	Yield per Acre
		lbs.			lbs.			lbs.
1	Check	4814	12	4-4-50, Seed-bed, August 21	10521	23	4-4-50, Seed-bed, August 21	8624
2	4-4-50, Seed-bed, August 21	8588	13	Check	4941	24	4-4-50, June 23, August 21	8135
3	4-4-50, June 23, August 21	8706	14	4-4-50, June 23, August 21	10104	25	Check	4543
4	Check	6670	15	4-4-50 July 18, August 21	8000	26	4-4-50, July 18, August 21	6303
5	4-4-50, July 18, August 21	10493	16	Check	4787	27	4-4-50, July 18, August 21	6356
6	4-4-50, July 6, August 21	8724	17	4-4-50 July 6, August 21	8316	28	Check	4624
7	Check	6755	18	2-3-50, June 23, August 21	6855	29	2-3-50, June 23, August 21	6665
8	2-3-50, June 23, August 21	10502	19	Check	4841	30	6-4-50, June 23, August 21	8316
9	6-4-50	10710	20	6-4-50, June 23, August 21	8163	31	Check	6402
10	Check	8172	21	4-4-50, June 23, August 7	8108	32	4-4-50, June 23, August 7	8766
11	4-4-50 June 23, August 21	10927	22	Check	4597	33	Check	6122

mixture gave the largest increase over the check plots. The 2-3-50 mixture gave good results and, in view of its low cost, is worthy of further consideration. The high cost of the 6-4-50 spray would not permit of its adoption. From the data secured no definite conclusions can be drawn.; for, while the results obtained would favor

early applications, it is believed that any increase of the early over the late applications was due more to the control of insects than of leaf-spot.

Experiments in 1917

From this brief summary of the previous work on the control of leaf spot, it is evident that while in some instances there was an increase in yield very little control resulted from spraying with Bordeaux mixture. It is highly desirable that tomatoes grown for the cannery be a deep red color and this cannot be had when the vines lose their leaves early in the season as the result of an attack of the leaf-spot fungus. The fruit from a vine of this kind is more likely to be small, irregular in size and yellow in color. In view of this fact, and the realization that the use of ordinary Bordeaux mixture has not, as a rule, controlled leaf spot, an effort was made to develop a spray mixture that would satisfactorily control the disease.

In the experiments conducted in 1917, 5 sprays were used; four of these were modifications of the standard Bordeaux mixture while one was of a different nature. The composition of each will be noted later. The standard Bordeaux mixture (4-4-50) also was used. This was done both to serve as a check on the other sprays and to determine if failure from its use in the past might be due to faulty methods or to spraying at the improper time. This criticism might be made of the work done at Salem in 1916. In this latter work, the spray applications were made at stated intervals so that it is possible that they were not made at the most opportune time. The work in 1917 was directed from a field laboratory where constant watch could be kept on the progress of the disease and spray applications made when they were most needed.

Spray Mixtures Used

The sprays used in the experiments of 1917 were prepared as follows:

1. *Standard Bordeaux Mixture,* 4-4-50. This mixture was prepared by diluting 4 gallons of the copper sulfate stock solution to 46 gallons and adding 4 gallons of the lime stock solution, stirring vigorously, during and following the addition of the lime stock solution.

2. *Standard Bordeaux Mixture with Resin Fish-Oil Soap,* 4-4-3-50. This was prepared exactly as the preceding except for the addition of soap (equal to 0.75 per cent) for each 50 gallons of the mixture. In making up this spray mixture, the materials without the soap were mixed and run into the spray tank. Three pounds of the soap in a solution of 1 pound to a gallon was then run into the tank. In making up the volume of copper sulfate and lime before the addition of soap, allowance was made for the amount of soap solution to be added later.

3. *Bordeaux Mixture with Resin Fish-Oil and decreased amount of Lime Soap,* 4-2-3-50. In this mixture the amount of lime used was but half the weight of the copper sulfate crystals, 3 pounds of the resin fish-oil soap being added for each 50 gallons of the mixture. With the change noted in the amount of lime used the spray was made up in the same manner as the preceding.

4. *Deka-Copper Sulfate Mixture with Resin Fish-Oil Soap*, 2-0.4-3-50. This mixture was prepared in accordance with Pickering's copper sulfate and lime water formula "C" (15) with the addition of soap at the rate of 3 pounds for each 50 gallons of the mixture. It was prepared by stirring into 40 gallons of clear saturated lime water, 2 pounds of copper sulfate solution and then diluting to 47 gallons. The mixture was then run into the spray tank and 3 gallons of the stock soap solution added.

5. *Copper-Soap Mixture*, 0.5-0-3-50. This mixture contains only copper sulfate and resin fish-oil soap in the proportions indicated in the formula.

In preparing this mixture ½ pound of copper sulfate in a solution of 1 gallon was diluted to 47 gallons and 3 pounds of soap in a solution of 3 gallons added. The soap was added after the copper sulfate solution was run into the spray tank.

In order that correct quantities of the various constituents of the above spray mixtures be measured out quickly, the following stock solutions and suspensions were prepared.

Copper Sulfate Solution. This was prepared in a 50-gallon barrel at the rate of 1 pound of the crystals to a gallon. The desired amount of water was added and the crystals dissolved by suspending them just below the surface in a burlap bag. When all were dissolved the solution was stirred to insure uniformity of concentration.

Milk of Lime. This was prepared at the rate of 1 pound to a gallon. Fifty pounds of lime was placed in a barrel and slaked by adding small quantities of water until the lumps had crumpled throughout. Water to make 50 gallons was added.

Resin Fish-Oil Soap Suspension. This suspension was made the same strength as the lime-water solution, 1 pound to a gallon. In getting large quantities into suspension, it was found necessary to employ hot water to hasten the process. After the soap was in suspension no serious trouble was had with its settling out.

Lime Water. This was prepared by slaking a quantity of lime in a barrel and adding water. The lime was then thoroughly stirred and allowed to settle. The clear liquid, a saturated solution of lime water, was drawn off as needed.

In the use of resin fish-oil soap with Bordeaux mixture no claims of priority can be made, as resin fish-oil soap as well as numerous other adhesives have been employed on various crops.

Shear (20) found that an adhesive was necessary in spraying cranberries, the waxy surface of these leaves causing the ordinary spray mixture to collect in drops and run off the leaf. He used resin fish-oil soap with good effect and it has since been adopted in cranberry spraying. Hawkins (9) demonstrated that 2 pounds of resin fish-oil soap added to 50 gallons of Bordeaux mixture gave better results than the Bordeaux without the soap. In the work here reported the soap was added to the Bordeaux mixture not only to increase its adhesiveness but also with the idea that the addition of the soap would increase its fungicidal value. The results of the experiments would indicate that this is true.

Halsted (8) employed a dilute copper sulfate solution for tomato spraying (1 ounce to 8 gallons of water), which was used with and without the addition of soap. The kind of soap used is not stated. He found that no control of tomato leaf spot resulted from the use of this spray. In the use of the copper-soap mixture employed in this work no injurious effects of any kind were noticed

on the sprayed plants. In a series of preliminary experiments, tomato plants in the seed-bed were sprayed with the 0.5-3-50 mixture and no injury of any kind resulted. The plants thus treated appeared to make a much more vigorous growth than similar untreated plants. In another test a 2-0-3-50 formula was used, that is, 2 pounds of copper sulfate and 3 pounds of soap to 50 gallons of water. Some of the young leaves on the plants sprayed with this mixture were slightly injured but the plants soon recovered.

In mixing the sprays it was found best to add the soap after the mixture had been run into the spray tank. If it is added in the mixing tank serious difficulties are encountered due to the formation of a large quantity of suds. In some cases where there was excessive agitation a heavy formation of suds resulted, but it was soon found that very little agitation was necessary to keep the mixture in suspension, and after this no trouble was experienced.

The advantages of the addition of soap were plainly seen, for not only did it increase the spreading quality of the spray mixture to a marked extent, but it also greatly increased its adhesiveness. Instances were noted where after a heavy rain the standard Bordeaux mixture was washed from the leaves, while the plants sprayed with the Bordeaux-soap mixtures were still white with the spray. This alone is of extreme importance, for the control of this or similar diseases by spraying depends on the presence of copper compounds on the leaf. Where the copper film is washed from the leaf soon after being applied, the leaf is liable to infection, while if it is retained, it serves as a constant protection.

Spraying Machinery

In connection with the tests of the different mixtures an effort was made to determine the method of applying the spray that would give best control. Two types of spray machinery were used. The first was a power sprayer furnished by the Truck Crop Laboratory of the Bureau of Plant Industry. This outfit was a 2-horse, 2-wheel cart with a 100-gallon tank. It was equipped with two lines of ½-inch hose, each 25 feet long, one from each side of the machine; to each hose was attached a 5-foot iron extension rod fitted with an angle nozzle. With this machine, it was possible to spray 11 rows in one trip through the field, 5 on each side of the machine and the row driven over. For the first several applications, a pressure of 150 to 175 pounds was maintained; for subsequent applications, this was increased to 200 to 225 pounds. At this pressure the spray was applied as a fine mist and the upper leaf-surfaces were well covered. It was found practically impossible to cover the lower leaf-surfaces entirely. This was especially true when the plants had reached maturity, when they broke and fell to the ground so that it was impossible to reach the lower surfaces of any but the uppermost leaves.

The other machine used was a traction sprayer, very much in favor with the growers in the southern part of the state. With this machine a pressure of 150 to 175 pounds was maintained. Three rows were sprayed at a time. For the first two appliceations, there were only 2 nozzles to a row. This was found to be unsatisfactory and a third one was added. The nozzles were so adjusted as to throw one spray downward upon the tops of the plants and one laterally from each side. An attempt to adjust the side nozzle so as to reach the under leaf-surfaces met with little success. It will be seen, however, that a very satisfactory control was obtained by the use of both of these machines, so that it would appear hardly essential that the lower leaf-surfaces be completely covered.

With the power machine, the spray mixtures were applied at the rate of 250 gallons to the acre. This is more than is usually applied in common practice but this amount was used in order that the plants be thoroughly covered. With the traction sprayer 175 gallons to the acre were applied. At the first applications, the plants were sprayed but once, while for subsequent applications each plot was sprayed twice, once each way, giving, in most instances, an ideal film.

Plan of the Experiments

Three sets of experiments were conducted. In the first, spray applications were made at approximately 10-day intervals during the summer. In this experiment, all the spray mixtures were tested as well as the two types of spray machinery. In the second experiment only two of the sprays were used and the number of applications was limited to two on some plots and three on others, the first application being made after the disease had made its appearance in the field. This was conducted to determine whether leaf-spot could be held in check after it had made its appearance on the plant. The third experiment was designed to determine the effect spraying a late variety would have on the ripening of the fruit.

Experiment with Spray Mixture and Machinery

The field in which this experiment was conducted was in tomatoes in 1914, okra in 1915 and tomatoes in 1916. After the 1916 crop was removed the field was put in rye; this was plowed under in the spring and fertilizer applied at the rate of 500 pounds to the acre before the plants were set out. This was made up of 500 pounds of tankage, 400 pounds of nitrate of soda and 2,000 pounds of acid phosphate. Shortly after the plants were established they were side-dressed with 300 pounds of fertilizer and again on July 7 with 350 pounds to the acre. For these two applications, the mixture was made up of 1,200 pounds of tankage, 400 pounds of nitrate of soda and 400 pounds of acid phosphate.

The plants were the Bonny Best, a second early variety very much in favor in the state. They were set out May 15, only thrifty plants being used. The rows were made 6 feet apart with the plants set 3 feet apart in the row. This was done to permit the use of the power sprayer, the tread of the machine making it impossible to employ the customary 5-foot row. The field as laid out contained 24 plots, each 6 rows wide, or approximately ½-acre. Between each plot a driveway was provided for by the omission of a row. This was done to facilitate spraying and the taking of yields. The employment of plots of this size eliminated, to a large extent, the extensive use of check plots to correct for possible differences in yield resulting from soil variations. The need of check plots in work of this nature is recognized, but in this experiment they were employed largely to show differences resulting from spray treatments so that their extensive use was hardly warranted.

Because of irregularities in the field the plots were not all the same size. In plots 23 and 24 a tree shaded some of the plants and these were discarded in taking yields. In computing the yields, the yield per plant for each plot was determined and from this the yield per acre was obtained. This method took into consideration any missing plants and thus gives the most accurate measure of the actual yield per acre. In taking yields, a count was made of the number of baskets from each plot, the yield in pounds per plot was then found by multiplying the total number of baskets by the average weight of a single basket which was obtained from the average weight of 1,000 baskets. This method was considered to be more accurate than attempting to weigh all the baskets in the field.

The 24 plots were divided into 4 series of 6 plots each. In each series there were 1 unsprayed and 5 sprayed plots. Two of these series, A and A1 were sprayed with the power sprayer, while the other two, B and B1 were sprayed with the traction sprayer. This gave four repetitions of each treatment. The four series were so arranged that the two methods of applying the spray alternated.

In the past it has been generally recommended that the plants be sprayed in the seed-bed. While this cannot be set aside from the results of 1 year's work, the results obtained would indicate that this was not necessary for the control of the disease. In view of the fact, however, that the presence of Bordeaux mixture on the young plants protects them from insect attacks, it might be advisable to spray in the seed-bed. It is a common practice in New Jersey to spray with an insecticide just after the plants are established in the field and again about 2 weeks later. Since this is true it would be well to use a combined insecticide and fungicide, which would take care of any early infection of leaf spot.

In 1917 little trouble was experienced with insects, consequently the early field applications were omitted. Applications were made

on the following dates, July 5, 12, 19, 30 and August 9, 17 and 27, making 7 sprays in all.

Table 11 gives the arrangement of the plots as they occurred in the field, and also the yield per acre for ripe and for green fruit as well as the total yield per acre. From the table it will be seen that the yield of plots receiving the same treatment, but in different parts of the experimental field, varies considerably. This,

TABLE 11

Yield of Tomato Spraying Experiments Conducted at Riverton

Treatment	Yield Per Acre		
	Ripe Fruit	Green Fruit	Total Yield
	lbs.	lbs.	lbs.
4-4-3-50	10,914	1,381	12,295
4-2-3-50	9,897	864	10,761
4-4-50	12,608	1,018	13,626
2-0.4-3-50	12,778	1,638	14,416
0.5-0-3-50	12,463	609	13,072
Check	11,107	139	11,246
4-4-3-50	12,947	1,011	13,958
4-2-3-50	12,391	1,769	14,160
4-4-50	15,198	1,327	16,525
2-0.4-3-50	15,464	2,313	17,771
0.5-0-3-50	13,697	2,313	16,010
Check	12,363	292	12,658
4-2-3-50	14,036	3,630	17,666
4-4-3-50	14,036	3,969	18,005
4-4-50	14,592	2,787	17,379
0.5-0-3-50	16,560	1,742	17,302
2-0.4-3-50	14,301	1,255	15,556
Check	13,043	221	13,264
4-2-3-50	15,512	3,242	17,256
4-4-3-50	15,415	1,841	17,256
4-4-50	15,599	1,473	17,072
4-4-50	15,599	1,473	17,072
0.5-0-3-50	13,939	1,870	15,804
2-0.4-3-50*	11,083	980	12,063
Check*	9,784	166	9,950

*The low yield from these plots is accounted for by the presence of a tree in the plot—this was taken into consideration in computing the yields per acre.

no doubt, can be traced to soil differences which in an experiment extending over so great an area cannot be prevented. By the use of large plots, however, and by repeating a treatment and its check four times, the differences resulting from the averages give a fairly accurate measure of the benefit derived from the treatment in question. It will be noticed also that the yield of green fruit is considerably greater from the sprayed plots than from those not sprayed. This may be accounted for by the fact that the sprayed vines remained vigorous for a longer period and, consequently,

were able to set and mature fruit much later in the season than the unsprayed vines. A large part of the fruit found late in the season did not ripen but this was not wholly a loss, as it is a common practice in New Jersey to pick the green fruit and cover it when a frost is expected. In this way a greater part of this fruit is ripened and, therefore, it may well be included in the total yields.

Efficiency of the Spray Mixtures. Before entering into a discussion of yields, the control resulting from the use of the different sprays will first be considered.

Leaf-spot was first observed in this field on July 13, only a few plants being affected. The disease had made but little progress from the point of initial infection when a period of extremely hot weather checked its advance, at the same time killing the lower leaves of most of the plants. On August 1 a thorough examination was made of all the plots, and no leaf-spot was observed. At this time, there was a week of wet, humid weather and the disease again made its appearance. A careful survey of the field was made on

TABLE 12

Per Cent of Dead Leaves on Each Plot and the Average for Each Treatment

Treatment	Dead Leaves				
	Series A	Series B	Series A1	Series B1	Average
	per cent	per cent	per cent	per cent	per cent
4-2-3-50	47	50	34	39	42
4-4-3-50	39	58	36	46	45
4-4-50	57	60	54	52	56
2-0-4-3-50 ..	56	66	58	58	60
0.5-3-3-50 ..	52	55	60	44	53
Check	95	94	96	96	95

August 13 and an estimate made of the number of infected leaves in the different plots. Of the check plots two showed 50 per cent infection, while the remaining two showed 80 per cent. Several of the sprayed plots likewise showed infection, but in these it was not more than 1 per cent. At the time of these observations, little difference was noticeable between the plots receiving the different treatments. As the season advanced, however, differences between the treatments became apparent but at all times the treated plots were markedly better than the untreated.

In order that a more accurate measure be had of the actual degree of control exhibited by the different sprays, an examination was made on September 7 to determine the per cent of dead leaves in each plot. It was impossible to do this for all the plants in a plot, so every tenth plant in the center row was taken. This esti-

mate was made to include all dead leaves whether present on the plant or missing. In table 12 is given the per cent of dead leaves for each plot as well as the average for each treatment.

At the time of these observations and for several weeks previous, the unsprayed plants were stripped almost bare of any leaves, only a few remaining at the apex. On this date the average number of dead leaves for the check plots was 95 per cent, as compared with 60 per cent for the poorest spray-plot. The Bordeaux-soap plots gave the best control, with the 4-2-3-50 mixture only 42 per cent of the leaves being dead. On the plots sprayed with the 4-4-3-50 mixture 45 per cent of the leaves were dead. The copper-soap mixture was third and gave slightly better results than the standard Bordeaux mixture. The plots sprayed with the Pickering mixture were poorer throughout the season than any of the other treated plots.

TABLE 13

Results of Five Years' Spraying Experiments Conducted at the Illinois Agricultural Experiment Station

Treatment	Relative Yield Per Plant: Early Fruit	Relative Yield Per Plant: Total Fruit
1. Check-Unsprayed	1.00 (1.27 lbs.)	1.00 (2.87 lbs.)
2. Every 2 weeks until close of shipping season	0.98	1.16
3. Every 2 weeks until plants were staked	0.85	1.12
4. Every 4 weeks throughout the season	0.79	1.41
5. Every 2 weeks until the shipping season	0.79	1.45
6. Sprayed throughout the season	0.85	1.64

While the best control resulted from the use of the Bordeaux-soap mixtures, the difference between the number of dead leaves on the best and the poorest spray-plot is not great. There is, however, a marked difference in the number of dead leaves between the treatment giving the best control and the check plots. In this connection, the question arises as to the effect holding all or a majority of the leaves until the end of the season will have on the ripening of the fruit. The results secured would indicate that there is a direct relation between the number of leaves retained and the amount of green fruit at the end of the season. The work of Lloyd and Brooks (12) would indicate that this is true. These investigators found that spray-applications greatly influenced the production of ripe fruit. The results of their experiments are summarized in table 13. The first column of the table gives the time of application, in the second column is given the average

yield in pounds per plant of marketable fruit picked at the close of the shipping season, and the third column gives the total yield of marketable fruit. In both cases, the results are the average of experiments conducted over a period of 5 years. Each record is expressed in terms of the corresponding figure for the unsprayed plants considered as unity, the actual weight of the fruit from the unsprayed plants being given in parenthesis, in pounds. The actual weight, in any case, may be obtained by multiplying the relative weight by the actual weight of the fruit from the control plants as given in the same column.

From the table it will be seen that the fruit picked for the early market is less on the sprayed than on the unsprayed plants. This, no doubt, may be attributed to the fact that the disease had not become severe so early in the season and, as a result, had not greatly interfered with the normal activities of the plant. Enough leaves were evidently lost from the unsprayed plants, however, to allow the sun to reach the fruit and thus hasten the ripening process. On the basis of total marketable fruit, however, there was a marked increase from the sprayed vines.

TABLE 14

Per Cent of Dead Leaves and Yield Per Acre For Each Treatment. Average of 4 Plots

Treatment	Dead Leaves	Green Fruit Per Acre	Ripe Fruit Per Acre
	per cent	lbs.	lbs.
4-2-3-50	42	2376	12,959
4-4-3-50	45	2050	13,328
0.5-0-3-50	53	1634	13,915
4-4-50	56	1651	14,697
2-0.4-3-50	60	1546	13,406
Check	95	204	11,577

It would appear that the presence of the spray on the leaves has a retarding influence on the ripening period. It is not believed that the spray exerts a direct influence, but that it functions indirectly in that the leaves are preserved from fungous attack and consequently shade the fruit, thus delaying its ripening.

In recent years, however, it has been felt that an application of Bordeaux mixture not only holds plant diseases in check but in some instances stimulates the plants treated to increased growth; this fact may account in part for the increased fruit from the sprayed vines, as well as the fact that the sprayed vines remained vigorous for a longer period than those which were unsprayed.

In table 14 is given the per cent of dead leaves for each treatment and the average weight of green and of ripe fruit.

In this table the spray treatments are not arranged in the order in which they occurred in the field, but in the order in

which they controlled the leaf spot, beginning with the spray giving the best control. It will be seen from the table that the treatment having the least dead leaves on August 7 gave the greatest amount of green fruit, and the treatment with the greatest number of dead leaves gave the least green fruit. On the other hand, the treatment with the least dead leaves gave lowest returns in ripe fruit, while, disregarding the 2-0.4-3-50 treatment, the treatments with the most dead leaves gave the highest yields of ripe fruit.

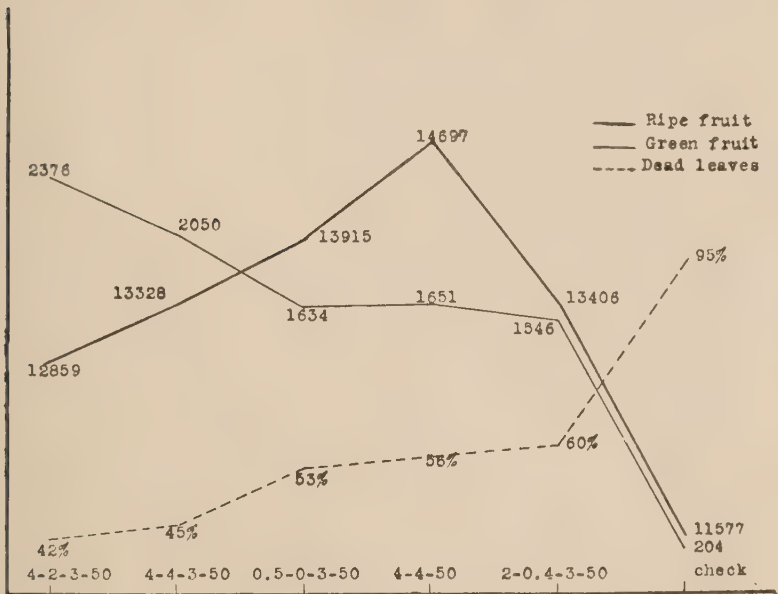

Fig. 1. Graphs Showing the Relation Between the Number of Dead Leaves and the Yield per Acre of Green and Ripe Fruit

To bring out better the relationship existing between the number of dead leaves and the amount of green and ripe fruit, the figures in table 14 are plotted to form the graphs shown in figure 1. Here the abscissas are taken arbitrarily to represent the different spray mixtures and the ordinates to represent the per cent of dead leaves as well as the weights of the green and ripe fruits. These graphs show a very clear relation between the number of leaves held and the amount of green and ripe fruit.

On the plots sprayed with the 4-4-50 mixture 56 per cent of the leaves were dead while on the best treatment, the 4-2-3-50, only 42 per cent of the leaves were dead. On a basis of ripe fruit the 4-4-50 treatment out-yielded the other by 1738 pounds, while with ripe fruit and green fruit the 4-2-3-50 treatment outyielded the 4-4-50 by 725 pounds. The same relations hold true with regard to the other plots.

A clear generalization is here indicated; the more green leaves, the greater is the amount of green fruit at the end of the season. This conclusion is perfectly definite for the data presented and appears to be what might be expected from an *a priori* consideration of the problem at hand.

The results would indicate that it is not desirable to hold all the leaves until the end of the growing season if all of the fruit is to be ripened. In New Jersey very little if any of the fruit set after September 1 will mature. While no definite statement can be made, it would appear desirable to hold most of the leaves until about September 1 and after that only enough to protect the fruit. It will be noticed from figure 1 that the greatest production of ripe fruit was on the Bordeaux-treated plots, on which 58 per cent of the leaves were dead by September 7. It would appear from this that greatest returns may be expected to follow where approximately 40 per cent of the leaves are retained.

Yields From Different Treatments. From the grower's viewpoint, success in spraying is a question of yield; where no increase is obtained the fact that a better quality of fruit will result from spraying will not be a sufficient incentive for him to undertake spray operations. In this season's work all the treated plots showed an increase over those not treated.

TABLE 15

Yield Per Acre For Each Treatment, Average of 4 Plots

Treatment	Green Fruit	Ripe Fruit	Total Yield	Increase of Green and Ripe Fruit Over Checks
	lbs.	lbs.	lbs.	lbs.
4-2-3-50	2376	12959	15335	3554
4-4-3-50	2050	13328	15379	3598
0.5-0-3-50	1634	13915	15548	3767
4-4-50	1651	14697	16348	4567
2-0.4-3-50	1546	13406	14952	3171
Check	204	11577	11781	

While the standard Bordeaux mixture did not give the best control, it will be seen from the table that it gave the largest increase over the unsprayed plots, a gain of 38 per cent.

The copper-soap mixture gave the next highest increase though the difference in the yields from these plots and the Bordeaux-soap plots was only 1 per cent; the former giving a 31 per cent increase over the check, while each of the Bordeaux-soap mixtures showed an increase of 30 per cent. The 2-0.4-3-50 mixture gave the poorest control of any of the sprays used and, at the same time, gave the lowest increase, 26 per cent over the check plots. The nature of this spray would tend to make its adoption for general spraying improbable, so it need not be discussed further. Eliminating this

treatment there was a difference of only 8 per cent between the best and the poorest treatment as compared with the check plots.

These differences are based on total yields, that is, green and ripe fruit combined. On the basis of ripe fruit alone the 4-4-50 treatments showed an increase of 27 per cent over the check plots, the 0.5-0-3-50 treatment 19 per cent, the 4-4-3-50 treatment 15 per cent, and the 4-2-3-50 treatment 11 per cent. Here again, is brought out the relation of the per cent of leaves held late in the season to the amount of fruit ripened. There is a difference of 16 per cent between the treatment giving the highest and the one giving the lowest yields of ripe fruit as compared with a difference of 8 per cent where total yield is considered. Where the yield of green fruit alone is considered, the plots sprayed with the 4-2-3-50 mixture gave an increase of 105 per cent over the check. The plots sprayed with the standard Bordeaux mixture gave 70 per cent more green fruit than the check plots.

TABLE 16

Per Cent of Dead Leaves on Plots Sprayed With the Traction and Power Sprayers

	Power Sprayer			Traction Sprayer		
Treatment	Series A	Series A1	Average	Series B	Series B1	Average
	per cent	per cent	per cent	per cent	per cent	per cent
4-2-3-50 ...	47	34	40	50	39	44
4-4-3-50 ...	39	36	37	58	46	52
4-4-50	57	54	55	60	52	56
2-0.4-3-50 .	56	58	57	66	58	67
0.5-0-3-50	52	60	56	55	44	49

While the copper-soap mixture did not give the best control it is, without doubt, the most desirable of all the mixtures used. Since it requires only ½-pound of copper sulfate and 3 pounds of soap to each 50 gallons of water, its use would mean a decided saving in the cost of materials over the present standard Bordeaux mixture in which 4 pounds of copper sulfate are used to each 50 gallons of the mixture. The ease with which the copper-soap spray is prepared and the fact that no lime is required are other factors very much in its favor. While it cannot be recommended from the results of one season's work to take the place of Bordeaux mixture, it is certainly worthy of future trial and should it prove as satisfactory as it has this year, there is little doubt but that it will be used rather than Bordeaux for tomato spraying.

Use of Traction and Power Sprayers. As has been previously stated, two of the four series, A and A1, were sprayed with a power sprayer, while the other two, B and B1, were sprayed with a traction sprayer. Several times during the summer trouble was experienced with the power sprayer when it appeared necessary

that applications be made at once, with the result that only 4 applications were made with the power sprayer and the other three with the traction sprayer. Since this is true no definite conclusions as to the relative merits of these two machines can be drawn from the data at hand.

In table 16 is given the per cent of dead leaves on the plots sprayed with the two types of machines, as well as the average for each treatment.

From the table it will be seen that on four of the five treatments there were less dead leaves on the plots where the power sprayer was used. In one instance, the plots treated with Bordeaux, the difference is only 1 per cent, while it is 14 per cent in the case of the 4-2-3-50 mixture. With the copper-soap mixture the plots sprayed with the traction sprayer showed 7 per cent less dead leaves than those sprayed with the power sprayer. This may be due to the fact that the copper-soap mixture gives best results when applied at a lower pressure than that developed by the power sprayer. The data at hand will not warrant any conclusions of this kind, however.

TABLE 17

Yield Per Acre of the Plots Sprayed with the Traction and Power Sprayers

	Power Sprayer			Traction Sprayer		
Treatment	Series A	Series A1	Average	Series B	Series B1	Average
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4-2-3-50	10,761	17,666	14,213	14,160	18,754	16,457
4-4-3-50	12,295	18,015	15,416	13,958	17,256	15,605
4-4-50 ...	13,626	17,379	15,502	16,525	17,072	16,798
2-0.4-3-50	14,416	15,556	14,986	17,771	12,063	14,917
0.5-0-3-50	13,072	17,302	15,187	16,010	15,809	15,909

While the differences are by no means great, there appears to be a tendency toward more complete control following the use of the power sprayer. In the use of this machine an effort was made to spray the under leaf-surface but only slight success was had, so any differences in favor of this machine over the traction sprayer are thought to be due more to the fact that the upper leaf-surfaces received a better covering.

In table 17 is given the total yield per acre of the plots sprayed with the power and traction sprayers as well as the average for each treatment.

It will be seen that in every case but one the plots giving the highest yield were sprayed with the traction machine. A study of the table, however, will show that the normal variation in yield between series A and A1 and between series B and B1, is greater than the differences between the averages. The varying factor in this case would appear to be the soil rather than the method of

applying the spray. In view of this fact, no conclusions can be drawn as to the most desirable method of applying the spray.

In view of the fact that the traction sprayer appears to have given as good results as the power sprayer, there is little to warrant the use of the latter machine. The cost of upkeep and running the power sprayer is considerably greater than for the traction sprayer and these factors would favor the use of the latter type of machine.

Effect of Late Spray Applications

The field in which this experiment was conducted received the same treatment as the first experimental field, with the exception that the plants were set out a week earlier. This land had been planted in tomatoes for 4 years and during that time leaf spot had been very severe.

TABLE 17

Yield of Plots Treated with Late Sprays

Treatment	Yield Per Acre	Treatment	Yield Per Acre
	lbs.		lbs.
1. Check	11,848	9. 0.5-0-305-	11,623
2. 0.5-0-3-50	13,391	10. Check	11,275
3. 0.5-0-3-50	11,848	11. 0.5-0-3-50	11,848
4. Check	9,856	12. Check	12,271
5. 4-4-3-50	12,719	13. 0.5-0-3-50	13,359
6. 0.5-0-3-50	14,909	14. Check	13,391
7. Check	10,952	15. 0.5-0-3-50	13,814
8. 4-4-5-50	11,176	16. Check	11,410

On July 18 most of the lower leaves of the plants in the field were infected with leaf-spot, and in most instances the fungus was fruiting. The purpose of the experiment was to determine whether the disease could be held in check after it had made its appearance, and by a limited number of spray applications. For this work only two of the spray mixtures, the 4-4-3-50 and the 0.5-0-3-50 were used. The sprays were applied with a traction sprayer at 150 pounds pressure, at the rate of 175 gallons to the acre. As in the previous experiment the plots were driven over twice, once each way, at each application.

The plots, as laid out, were approximately ½-acre in size. Each plot was 3 rows wide and so arranged that each treated plot was adjacent to an untreated plot. In table 17 is given the arrangement of the plots with the yield per acre for each plot. Plots 11, 13 and 15 were sprayed on July 21 and 31 while the remaining treated plots received a third application on August 11.

When on August 24 a thorough examination was made of the different plots, the ones sprayed three times were found to be almost free from any new infection, while the check plots were heavily infected. On the plots sprayed twice there was considerable infection, but these plots were decidedly better than their adjoining checks.

On September 5 another observation was made. At this time the plots sprayed twice were little better than the unsprayed plots. This was to be expected, since the last application of spray was made July 31 and had, without doubt, been washed from the plants long before this, leaving them unprotected. The plots sprayed three times were still decidedly better than the unsprayed checks; a greater part of the leaves being diseased, but still green, while on the unsprayed plants only a few green leaves remained at the apex of the branches. Table 18 gives the average yield per acre of the plots receiving two applications of spray and of their adjoining checks.

TABLE 18*

Yield of Plots Receiving Two Applications of Spray

Treatment	Yield Per Acre	Increase Over Checks
	lbs.	lbs.
0.5-0-3-50	13,007	920
Check	12,387	...

Two applications of the copper-soap mixture gave an increase of 920 pounds over their adjoining checks. It is true that there is a large normal variation between the check plots, but inasmuch as the treatment and its check was repeated three times, the differences resulting from the averages may be attributed largely to the spray treatment.

In table 19 is given the average yield in pounds per acre of the plots sprayed three times and of their adjoining checks.

TABLE 19

Yield of Plots Receiving Three Applications of Spray

Treatment	Yield Per Acre	Increase Over Check
	lbs.	lbs.
4-4-3-50	12,428	1543
Check	10,885	....
0.5-0-3-50	12,880	2106
Check	10,694	....

It will be seen from table 19 that the plots receiving three applications of spray gave a considerable increase over their checks. It will be noticed also that the plots sprayed with the copper-soap mixture gave a greater increase than did the Bordeaux-soap mixture, being 19 per cent and 14 per cent, respectively. In the first experiment the plots sprayed with the copper-soap mixture likewise outyielded those sprayed with the Bordeaux-soap mixture, though the use of the latter mixture gave slightly better control. In this experiment very little difference was observed between the two treatments.

The results of this experiment would indicate that leaf spot can be held in check after it appears in the field; also, they would emphasize the point brought out by the first experiment, namely, that early applications are not essential for the control of the disease. The necessity of late applications is demonstrated conclusively. The plants sprayed twice were dead some time before those which received a third application at a later date, and there is no reason to doubt that, had a fourth application been made, these plants would have remained green for several weeks longer.

The results of this and the first experiment demonstrated beyond a doubt that this disease can be controlled by spraying, but they also emphasize the importance of spraying at the proper time. A few applications made indiscriminately cannot be expected to give satisfactory results.

TABLE 20

Plot Yields Per Acre in Experiment with Late Tomatoes

Treatment	Ripe Fruit	Green Fruit	Total Yield
	lbs.	lbs.	lbs.
Check	10,955	2,112	13,067
4-2-3-50	11,203	4,225	15,428
0.5-0-3-50	9,648	3,703	13,351
Check	9,365	2,896	12,261
0-0-3-50	8,581	3,158	11,739
2-0.4-3-50	8,712	5,009	13,721
Check	7,252	2,635	9,887
4-2-3-50	8,538	5,009	13,547
0.5-0-3-50	8,276	3,158	11,434
Check	10,019	2,374	12,393
0-0-3-50	10,539	2,896	13,436
2-0.4-3-50	10,628	3,419	14,047
Check	10,345	1,847	12,192
4-2-3-50	11,986	3,158	14,244
0.5-0-3-50	10,409	2,374	12,784
Check	11,674	1,187	12,861
0-0-3-50	11,042	1,847	12,889
2-0.4-3-50	10,498	1,847	12,345
Check	10,606	1,317	11,923

Experiments with Late Tomatoes

This experiment was designed to determine what effect spraying would have on late tomatoes. The soil in the field in which the experiment was conducted was much heavier than that in the other two. Before the plants were set out 600 pounds to the acre of the following mixture was applied: 1400 pounds of phosphoric acid, 200 pounds of nitrate of soda and 400 pounds of tankage.

The tomatoes were of the variety Greater Baltimore, a late tomato extensively grown in this part of the state. The plots were laid out as in the preceding experiment, and the following spray mixtures were used: 4-2-3-50, 0.5-0-3-50; 2-0.4-3-50 and 0-0-3-50. The last named was resin fish-oil soap used at the rate of 3 pounds

to each 50 gallons of water; this was used to determine whether or not the soap had any fungicidal value. Applications were made on the following dates: July 31, August 13, August 19, August 28, September 3, and September 11, making six in all. In table 20 is given the arrangement of the plots the yield in both ripe and green fruit, and the total yield per acre.

Leaf-spot was not observed in this field until September 5; in the following week it was widespread though it never became severe. On October 21 careful observations were made to determine the per cent of dead leaves in each plot following the plan outlined in the first experiment. Table 21 shows the results.

TABLE 21

Dead Leaves in Plots of Late Tomatoes

Treatment	Dead Leaves Found			
	Series 1	Series 2	Series 3	Average
	per cent	per cent	per cent	per cent
4-2-3-50	33	41	53	47
0.5-0-3-50	40	53	61	51
2-0.4-3-50	45	62	57	54
0-0-3-50	45	62	57	54
Check	67	73	85	75

At the time of this observation the unsprayed plants were still in fairly good condition, the leaves showing very little infection and having a good green color.

Of the treated plots, those sprayed with the 4-2-3-50 mixture were the best, being slightly better than those sprayed with the copper-soap mixture. The difference was not marked, however. The plots treated with the soap solution were better than those not treated, as there were 13 per cent less dead leaves on the former than on the latter. This would indicate that resin fish-oil soap has some fungicidal value.

It will be noticed, however, that the difference between the number of dead leaves for the various treatments is by no means great, and also that there is no marked difference between the treated and the untreated plots. This is explained by the fact that very little disease was present in this field until late in the summer. In view of this fact, the differences resulting from the different treatments were not large. In table 22 is given the average yield per acre in pounds of green and ripe fruit for the different treatments as well as for the unsprayed checks. The total yield per acre and the differences resulting from the treatments also are given.

The data in table 22 would indicate that the Pickering Bordeaux mixture gave as good results as the Bordeaux-soap mixture. Both of these treatments gave an increase of approximately 1 ton to the acre over their adjoining checks. The copper-soap and resin

fish-oil soap mixtures both gave slight increases, but these are well within experimental error, so in this experiment no indicative results can be attributed to these two sprays. Why two of the mixtures should give increased returns and the copper-soap spray should not, is rather difficult to explain in the light of the first two experiments where the copper-soap mixtures out-yielded the Bordeaux-soap mixtures.

The results secured would indicate that in this instance it did not pay to spray. This variety of tomato is very late in ripening its fruit and where the greater part of the leaves have been held until frost the ripening process is still further delayed so that a large portion of the fruit will not ripen. In this experiment the average amount of green fruit picked from the sprayed plots

TABLE 22

Yields Per Acre of Late Tomatoes, According to Treatments, Average of Three Plots

Treatment	Ripe Fruit	Green Fruit	Total Yield	Increase over Check
	lbs.	lbs.	lbs.	lbs.
0-0-3-50	10,054	2,634	12,688	184
Check	9,517	2,198	11,715	.....
4-2-3-50	10,275	4,130	14,405	2,690
0.5-0-3-50	9,445	3,078	12,523	19
Check	10,352	2,152	12,504	.....
2-0.4-3-50	9,946	3,425	13,371	2,037
Check	9,401	1,933	11,334	.....

was 85 per cent more than from the unsprayed. However, no statement to the effect that it does not pay to spray late tomatoes can be made, since in a field adjoining this, planted to the same variety, but set out a week earlier, the plants were killed early in the season. In this case there is no doubt that spraying would have given returns. Just why this difference should exist in the amount of disease present in the two fields is difficult to state. The field in which the experiment was conducted was high and well drained, while the other was low and comparatively wet, so that there may be some relation between environmental factors and the prevalence of the disease. Several other instances were noted during the summer where the disease first made its appearance in the lower portions of a field.

The results of this experiment and these observations would indicate the impossibility of making any fixed dates on which to spray. The appearance of the disease seems to be determined largely by local conditions and results will be secured only through the efforts of the grower to make applications at the most opportune time.

Summary

1. Leaf-spot of tomatoes caused by *Septoria lycopersici* Speg. causes serious losses to the tomato growers in New Jersey.

2. The disease attacks the stems and leaves, causing the defoliation of the plant. Fruit from a diseased plant is of inferior quality, both as to color and as to texture.

3. The disease appears about July 1. When the epiphytotic stage is reached all the plants in a field are soon attacked.

4. Studies on the dissemination of the causal organism show that:

(a) Insects may carry large numbers of the spores. Positive results were obtained from insects in the following families: (1) *Sphingidae* (2) *Chrysomelidae* (3) *Coccinellidae*.

(b) Insects were found to carry spores other than those of *Septoria lycopersici*. Spores of the early-blight fungus were found in large numbers.

(c) Both *Septoria* and *Alternaria* spores were found in insect excrement. Alimentation does not greatly lessen their viability.

(d) Wind and water likewise were found to function in the distribution of the leaf-spot organism. Their combined action no doubt goes far to explain the rapid spread of the disease from infection centers.

(e) Pickers also were found to carry large numbers of the spores on their hands and garments. The results secured emphasize the fact that picking should be delayed after a rain or heavy dew until the plants are dry.

5. Disease-control studies have shown that:

(a) While increased yields have resulted from the use of Bordeaux mixture very little control resulted. In the spraying experiments with Bordeaux mixture in 1916 the sprayed plants appeared little better than the unsprayed.

(b) The spray mixtures used in 1917 were found to control leaf-spot in the following order: (1) 4-2-3-50, (2) 4-4-3-50, (3) 0.5-0-3-50, (4) 4-4-50, (5) 3-0.4-3-50.

(c) The standard Bordeaux mixture (4-4-50), while it did not give the best control, gave the greatest increase in yield over the check plots.

(d) The use of the copper-soap mixture (0.5-0-3-50) gave good results, both as to control and as to yield. Because of its low cost and ease of preparation, it should be given serious consideration.

(e) The Bordeaux-soap mixtures (4-2-3-50) and (4-4-3-50) gave the best control.

(f) Pickering's Bordeaux mixture (2-0.4-3-50) would be of little value for extensive spray operations.

6. Little difference resulted from the use of the traction and power sprayers. The traction sprayer, however, because of its low cost of upkeep, would appear to be the better.

7. It is not necessary to spray plants in the seed-bed in New Jersey for the control of leaf-spot. It would appear, also, that the early applications in the field are not necessary for its control. The first application, however, should not be made later than July 1.

8. It is not believed that the presence of Bordeaux mixture, or modifications of this mixture, on the plant has any direct influence on the ripening period. It does function indirectly however, in that it preserves the foliage by protecting it from fungous attack, in this way delaying ripening. Where all the leaves are thus held to the end of the season, a large part of the fruit will not ripen.

9. Under certain conditions the advisability of spraying late varieties of tomatoes is questionable.

10. Leaf-spot may be controlled by thorough spraying, but it is important that the application be made at the proper time. A few applications made indiscriminately will not give satisfactory results.

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PLATE 1.

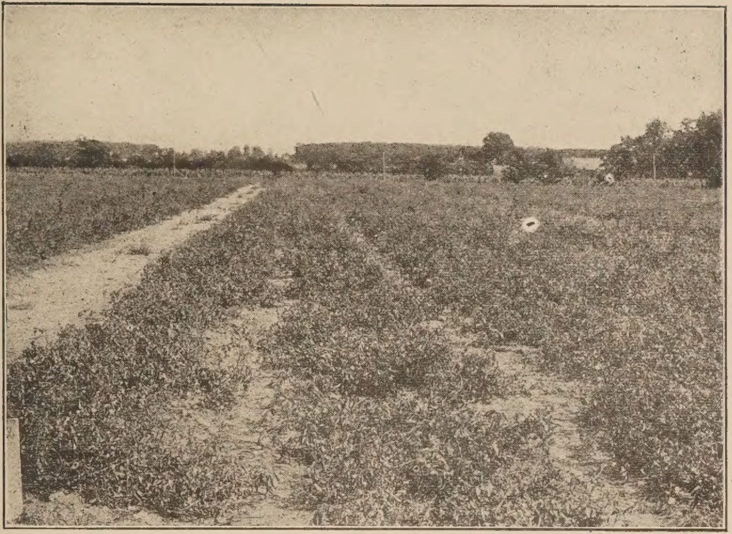

Fig. 1. Sprayed with 3-2-3-50 mixture.

Fig. 2. Unsprayed check.